Original Clinical Article

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Slipped capital femoral epiphysis: a spectrum of surgical care and changes over time

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Abstract

Purpose To survey the spectrum of surgical care in children with slipped capital femoral epiphysis (SCFE). This information is valuable in counselling the patient about the future treatment course.

Methods Data for this study were obtained from the Pediatric Hospital Information System (PHIS) between 2004 and 2015. For all patients with an ICD9 diagnosis of 732.2, gender, ethnicity, hospital, medical record number, date of birth/admission/discharge, type of admission, length of stay, disposition and treatment(s) rendered were collected.

Results A total of 13 168 procedures were performed in 11 058 unique SCFE patients, or 1.2 procedures per patient. Primary procedures were those performed for the initial treatment of the SCFE and secondary procedures as reconstructive and salvage. The majority (11 693, 88.8%) were primary. There was significant variation in the ratio of primary and secondary procedures by institution. There was a decline in *in situ* fixation as the initial SCFE treatment with an increase in open reduction and internal fixation over the 12-year span. Similarly, there was a significant increase in the number of secondary procedures over time as well as complications and implant removal. There was no change over time in the diagnosis of avascular necrosis.

Conclusions The average number of surgical procedures in patients was in the range of 1 to 6 and varied widely by hospital. Each physician should know his/her own hospital's data for the percentage of subsequent procedures so as to counsel the patient and family properly. The increasing number of complications over time may reflect the increasing number of more complex procedures.

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Introduction

Treatment options for slipped capital femoral epiphysis (SCFE) range from *in situ* single screw fixation to more complex surgeries, such as osteotomy with or without surgical hip dislocation.[1,2] Residual deformity or complications that have arisen from the initial treatment may require further surgical procedures. Most studies of SCFE treatment involve the techniques and/or outcomes of one particular method or, occasionally, a comparison of two. To our knowledge, there is no study following a large cohort of patients over a spectrum of care. Such information would be very valuable to the treating physician so as to more fully inform the parents of a child with SCFE, upon initial visit/presentation, what a potential treatment course is. It is the purpose of this study to survey a spectrum of surgical care in children with SCFE.

Patients and methods

Data for this study were obtained from the Pediatric Hospital Information System (PHIS), an administrative database that contains inpatient, emergency department, ambulatory surgery and observation encounter-level data from over 45 not-for-profit, tertiary care paediatric hospitals in the United States. These hospitals are affiliated with the Children's Hospital Association (Overland Park, KS). Data quality and reliability are assured through a joint effort between the Children's Hospital Association and participating hospitals. Portions of the data submission and data quality processes for the PHIS database are managed by Truven Health Analytics (Ann Arbor, MI). For the purposes of external benchmarking, participating hospitals provide discharge/encounter data including demographics, diagnoses and procedures. Nearly all of these hospitals also submit resource using data (e.g. pharmaceuticals, imaging and laboratory) into PHIS. Data are de-identified at the time of data submission and data are subjected to a number of reliability and validity checks before being included

in the database. For this study, data from 49 PHIS hospitals were used. The study was determined to be exempt by our local Institutional Review Board.

From the PHIS database, the following information was obtained for the years between 2004 and 2015 for all patients having an ICD9 diagnosis of 732.2 (non-traumatic SCFE): gender; ethnicity; hospital; medical record number; date of birth/admission/discharge; type of admission; length of stay; disposition; and treatment(s) rendered. Treatment episodes for non-SCFE-related issues were deleted (e.g. emergency room visits for asthma, etc). Since this study straddled the transition between ICD9 and ICD10 codes (the last three months of 2015), only data using ICD9 codes were used to minimise errors in reporting that must certainly have occurred in the early ICD10 reporting era.

Statistical analyses

Continuous data are reported as the mean ± 1 standard deviation. Discrete data are reported as frequencies and percentages. Analyses between groups of continuous data were performed with non-parametric tests (Mann-Whitney U test: two groups; Kruskal-Wallis test: three or more groups) due to skewed non-normal distributions. Differences between groups of discrete data were analysed by Fisher's exact test (2 × 2 analyses) or the Pearson's χ^2 test (>2 × 2 analyses). Trends over time were analysed using linear regression to obtain a linear fit, r^2 and p-value. Statistical analyses were performed with Systat 10 software (Chicago, IL, USA, 2000). For all statistical analyses, $p < 0.05$ was considered statistically significant.

Results

A total of 13 168 procedures were performed in 11 058 unique SCFE patients, or 1.2 per patient. The number of procedures performed was one in 9219 patients (83.37% of the procedures), two in 1613 (14.59%), three in 192 (1.74%), four in 25 (0.23%), five in seven (0.06%) and six in two patients (0.02%). The diagnoses for which these procedures were performed are shown in Table 1 and the types of surgical procedures are shown in Table 2. The vast majority were performed for treatment of the SCFE (96.4%).

The procedures were designated as either primary or secondary (Tables 3 and 4). Primary procedures (Table 3) were considered to be those performed for the initial treatment of the SCFE and were defined as internal fixation *in situ*, closed and/or open reduction with internal fixation, and epiphysiodesis; all others were considered to be secondary. Secondary procedures were subsequently divided into reconstructive (osteotomy, hip reconstruction, implant removal) and salvage (hip replacement and arthrodesis) (Table 4). Although osteotomy may be either a primary or secondary procedure, the number of osteotomies performed as a percentage of all procedures was small (396, 3.01%) and was arbitrarily designated as secondary. This arbitrary designation is supported by the fact that the average age of the patients in the primary procedure group was 12.5 ± 1.8 years compared with 14.6 ± 2.4 years for the osteotomy group.

Table 1. Surgical indications for 11 058 patients with SCFE.

Problem/Diagnosis	N	%
SCFE and/or residual deformity	12 693	96.39
Complication of device	337	2.56
Avascular necrosis	87	0.66
Fracture	35	0.27
Dislocation	7	0.05
Genu valgum	7	0.05
Infection	2	0.02
Total	13 168	100

Table 2. A total of 13 168 surgical procedures performed in 11 058 patients with SCFE.

Procedure	n	%
SCFE treatment	12 089	91.81
IFIS	8822	67.00
CRIF	1790	13.59
ORIF	791	6.01
Osteotomy	396	3.01
Epiphyseodesis	290	2.20
Implant removal	273	2.07
Reconstructive and salvage procedures	470	3.57
Hip reconstruction*	307	2.31
Hip arthroplasty	48	0.36
Biopsy and/or treatment of a lesion	30	0.23
Arthrogram	28	0.21
Bone graft	26	0.20
Injections/arthrocentesis	16	0.12
Arthrodesis	15	0.14
Miscellaneous procedures	81	0.62
Limb lengthening	15	0.11
External fixator application	14	0.11
Tenotomy/synovectomy	12	0.09
Open reduction of hip	11	0.08
Closed reduction of hip dislocation	8	0.06
Limb length equalisation	7	0.05
Excision	6	0.05
Infection treatment	5	0.04
Arthroscopy	3	0.02
Unknown/Not described	255	1.94
Total	13 168	100

IFIS, internal fixation *in situ*; CRIF, closed reduction internal fixation; ORIF, open reduction internal fixation

*Details of reconstruction not defined

Table 3. Primary surgical procedures for SCFE.

	Primary vs. secondary			Within primary				
Variable	**Primary (%)**	**Secondary (%)**	**p-value**	**IFIS (%)**	**CRIF (%)**	**ORIF (%)**	**Epiphyseodesis (%)**	**p-value**
All SCFEs	11693 (88.80)	1475 (11.2)	-	8822 (75.4)	1790 (15.3)	791 (6.8)	290 (2.5)	-
Age (yrs ± 1 sd)	12.5 ± 1.8	14.3 ± 2.9	$< 10^{-6}$	12.4 ± 1.8	12.5 ± 1.8	12.9 ± 2.2	12.6 ± 1.8	$< 10^{-6}$
Gender								
Female	4339 (87.89)	598 (12.11)	0.011	3232 (36.6)	670 (37.4)	319 (40.3)	118 (40.7)	0.11
Male	7354 (89.35)	877 (10.65)		5590 (63.4)	1120 (62.6)	472 (59.7)	172 (59.3)	
Race								
White	5578 (87.54)	794 (12.46)	0.00008 0.000001†	4170 (56.4)	845 (55.2)	408 (62.0)	155 (63.5)	0.016 0.008†
Black	4028 (90.52)	422 (9.48)		3052 (41.3)	650 (42.5)	238 (36.2)	88 (36.1)	
Asian	98 (88.29)	13 (11.71)		76 (1.0)	20 (1.3)	1 (0.2)	1 (0.4)	
Native American	83 (91.21)	8 (8.79)		66 (0.9)	9 (0.6)	8 (1.2)	0 (0.0)	
Polynesian	41 (87.23)	6 (12.77)		31 (0.4)	7 (0.5)	3 (0.5)	0 (0.0)	

IFIS, internal fixation *in situ*; CRIF, closed reduction internal fixation; ORIF, open reduction internal fixation

† p-value for Black and White patients only

Table 4. Secondary surgical procedures for SCFE.

	Within secondary - reconstructive				Within secondary - salvage		
Variable	**Hip reconstruction - other (%)**	**Osteotomy (%)**	**Implant removal (%)**	**p-value**	**Arthrodesis (%)**	**Hip replacement (%)**	**p-value**
All SCFEs	287 (30.3)	387 (40.9)	273 (28.8)	-	15 (24)	48 (76)	-
Age (yrs ± 1 sd)	15.5 ± 3.2	14.6 ± 2.4	13.4 ± 2.1	$< 10^{-6}$	13.4 ± 2.1	15.3 ± 2.8	0.042
Gender							
Female	134 (46.7)	147 (38.0)	117 (42.9)	0.039	7 (47)	14 (29)	0.23
Male	153 (53.3)	240 (62.0)	156 (57.1)		8 (53)	34 (71)	
Race							
White	154 (64.4)	211 (64.0)	149 (64.5)	0.487	4 (33)	25 (66)	0.13 0.041
Black	78 (32.6)	112 (34.0)	80 (34.6)	0.95†	8 (67)	11 (29)	
Asian	6 (2.5)	3 (0.9)	1 (0.4)		0 (0.0)	1 (3)	
Native American	0 (0.0)	2 (0.6)	1 (0.4)		0 (0.0)	1 (3)	
Polynesian	1 (0.4)	2 (0.6)	0 (0.0)		0 (0.0)	0 (0.0)	

† p-value for Black and White patients only

The majority of the procedures performed (11 693, 88.8%) were for the initial treatment of the SCFE, with the remaining (1475, 11.20%) being secondary. There was significant variation in the ratio of primary and secondary procedures by institution (Fig. 1). The procedures were also divided into those treating the SCFE itself (n = 12 702, 96.46%) and those due to a complication of SCFE treatment (n = 466, 3.54%) (Table 5). A complication was defined as a fracture, avascular necrosis, infection, dislocation of the hip or problems with internal fixation.

Trends over time

There was a statistically significant increase in the number of secondary procedures over time (Fig. 2), as well as all complications of treatment and implant removal (Fig. 3). There was no change in the diagnosis of avascular necrosis. There was a significant decline in *in situ* fixation

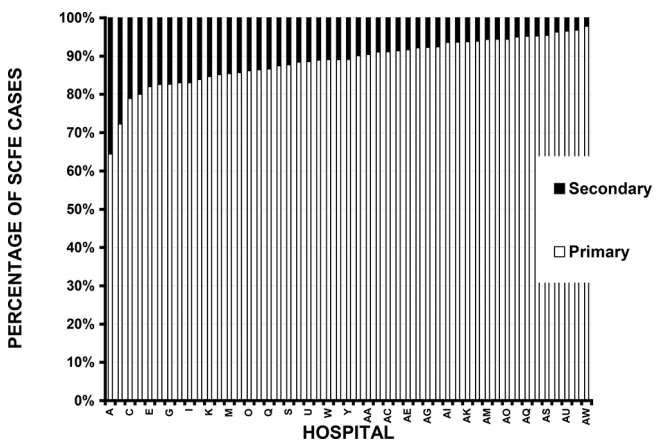

Fig. 1 Primary and secondary procedures for SCFE between different children's hospitals. The lowest proportion of primary procedures was hospital A (64.4%) and the highest was hospital AW (97.8%). This difference was statistically significant, $p < 10^{-6}$.

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Table 5. SCFE procedures over time by the presence or absence of complications.

Year	No complication	Complication	Nature of complication				
			Internal fixation problems	Fracture	Avascular necrosis	Hip dislocation	Infection
2004	903	21	13	1	7	0	0
2005	884	22	16	1	5	0	0
2006	927	20	10	3	6	1	0
2007	1021	27	20	1	6	0	0
2008	1024	39	30	2	6	1	1
2009	1093	44	34	6	4	0	1
2010	1164	40	31	1	8	0	0
2011	1265	57	45	2	8	2	0
2012	1181	49	35	3	10	1	0
2013	1200	63	47	5	11	0	0
2014	1125	48	32	4	11	1	0
2015	915	36	24	6	5	1	0
All years	12 702	466	337	35	87	7	2

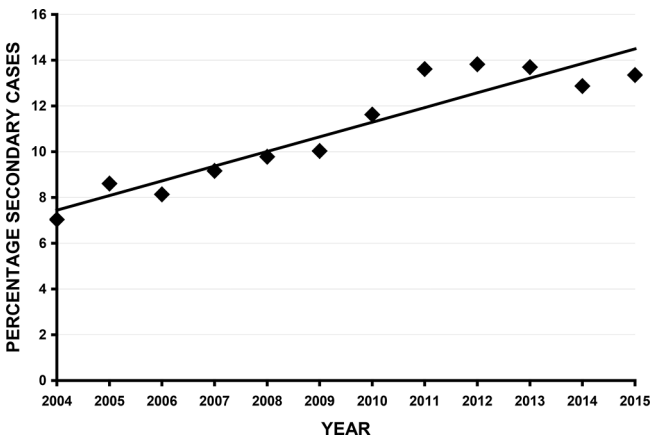

Fig. 2 Increasing proportion of secondary procedures for SCFE over time. The best fit equation is represented by the equation: percentage of secondary procedures = -12.77 + 0.608 (year), r^2 = 0.88, p = 0.000008. The number of secondary procedures for each year is shown by the filled rhomboids and the best fit linear regression the bold line.

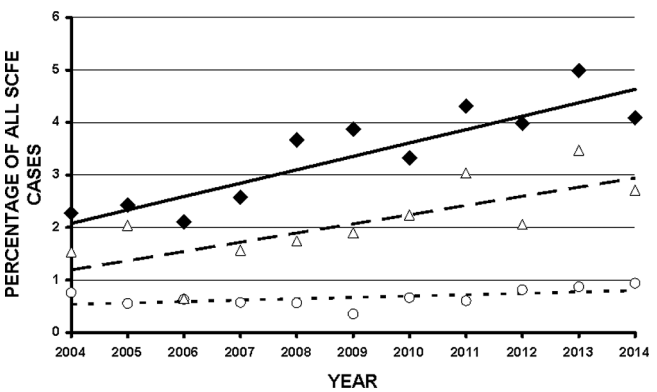

Fig. 3 Increasing proportion of procedures due to complications of SCFE treatment over time. The overall prevalence of complications for each year is shown by the filled rhomboids and the best fit a solid line represented by the equation: percentage = -509.3 + 0.255 (year), r^2 = 0.79, p = 0.00023. The percentage of implant removal for each year is shown by the open triangles and the best fit is shown by the long hatched line, represented by the equation: percentage = -349.31 + 0.175 (year), r^2 = 0.56, p = 0.008. The percentage of avascular necrosis for each year is shown by the open circles and the best fit is shown by the short hatched line, represented by the equation: percentage = -51.95 + 0.026 (year), r^2 = 0.28, p = 0.15.

and epiphyseodesis as the initial SCFE treatment (Fig. 4a) with a significant increase in open reduction and internal fixation (Fig. 4b). For the analysis of complications, 2015 data were excluded, since many complications may not become apparent for at least one year after the index procedure. Terminating the analyses at 31 December 2014 was done to minimise this concern.

Hip replacement and arthrodesis

Hip replacement or arthrodesis is a salvage procedure for any SCFE patient, and these were specifically investigated. Hip replacement was performed in 48 and arthrodesis in 15 patients. These 63 patients underwent a total of 111 procedures; there was no difference in the average number of procedures between the two groups (1.6 ± 0.7 arthrodesis, 1.8 ± 0.9 hip replacement, p = 0.65). The average age at the initial SCFE treatment, although not statistically different between the hip replacement (13.3 ± 1.5 years) and arthrodesis (12.1 ± 1.3 years) groups (p = 0.069), demonstrated a trend towards significance. The average age at the time of hip replacement (15.3 ± 2.8 years) was older than for arthrodesis (13.7 ± 2.8 years) (p = 0.042). There were no differences by gender. There was a difference by race; four of the 29 (14%) Caucasian patients underwent arthrodesis compared with seven of 16 (44%) Black patients (p = 0.035).

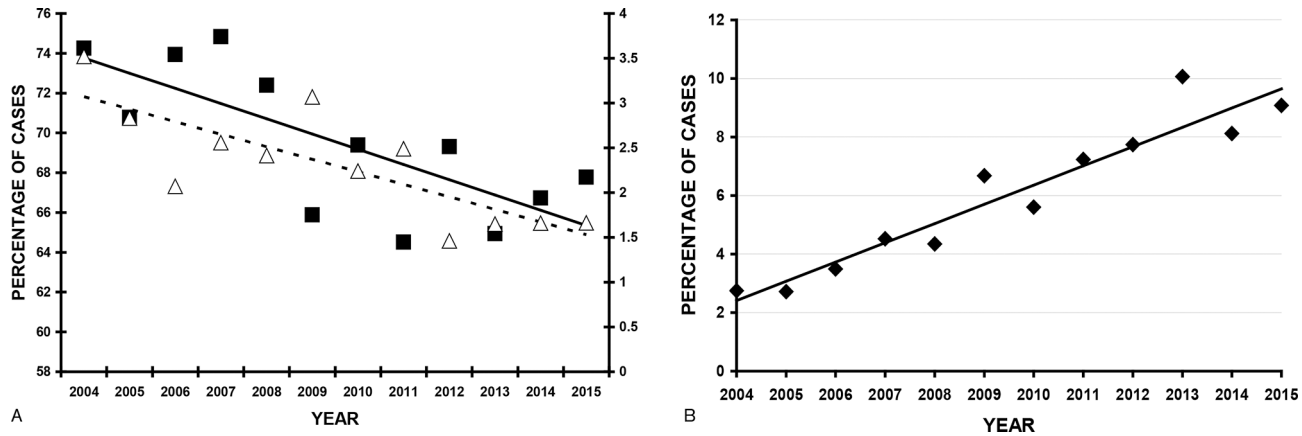

Fig. 4 Graphs demonstrating changes over time for the initial treatment in children with SCFE. (**a**) A decrease in both internal fixation *in situ* and epiphyseodesis as the initial treatment of SCFE over time. For internal fixation *in situ*, the percentage of cases is shown in solid squares and the best fit linear regression the bold line, represented by the equation: percentage of cases = 1607 - 0.7651 (year), $r^2 = 0.56$, p = 0.0058. For epiphysiodesis, percentage of cases is shown in open triangles and the best fit linear regression is shown by the dotted line represented by the equation: percentage of cases = 283.5 – 0.140 (year), $r^2 = 0.62$, p = 0.002. (**b**) An increase in open reduction internal fixation as the initial treatment of SCFE over time. The percentage of cases is shown by the filled rhomboids and the best fit linear regression the solid line, represented by the equation: percentage of cases = -1315 + 0.657 (year), $r^2 = 0.90$, p = 0.00002.

Discussion

The limitations of this study must first be acknowledged. As with any large national database, there are always potential entry errors. Second, not all 49 hospitals began participating in PHIS the same year. Of the 49 hospitals, 37 submitted data beginning in 2004 which accounts for 92.4% of the 13 168 procedures. The data from the hospitals more recently submitting data to PHIS will not demonstrate as long a course of follow-up, such as subsequent procedures or the development of a complication. However, this would only underestimate the number of secondary procedures or complications. Thus, the results of this study are conservative values. Finally, complications in adults from inappropriate *in situ* pinning leading to early osteoarthritis would not be captured by the database.

With these caveats in mind, several interesting findings were noted. Between 2004 and 2015, there was a gradual decrease in the percentage of *in situ* fixation and epiphyseodesis performed as the initial treatment, with an increase in the percentage treated with open reduction and internal fixation. This may reflect the hip preservation movement[3] with the modified Dunn osteotomy approach.[4-7] At the same time, there was an increase in the percentage of surgical cases for complications as well as implant removal. There was no significant change in the percentage of cases for the treatment of avascular necrosis (AVN). It is well known that AVN is primarily associated with unstable SCFEs[8-12] and/or osteotomies close to the physis.[13] The PHIS data are not detailed enough to know the stable/unstable nature of the SCFE or the exact type of osteotomy (e.g. intertrochanteric, basilar neck, transphyseal) or other hip reconstructions that were performed since it uniformly uses the ICD9 PX codes. The more detailed CPT codes are infrequently entered.

The average number of surgical procedures in patients with SCFE was 1.2, with as many as six. The majority (88.8%) were performed for initial SCFE treatment, with the remaining (11.20%) being subsequent procedures. Depending upon the hospital, this percentage varies widely. This is important information when counselling a family whose child has been newly diagnosed with a SCFE. The initial procedure may be followed by subsequent procedures 11% of the time; each physician should know his/her own hospital's data for this percentage of subsequent procedures so as to counsel the family properly.

There are several potential explanations for the marked differences in primary and secondary procedures by hospital. One explanation is that it represents different philosophies of treatment, with some hospitals being more aggressive in later re-alignment/reconstructive procedures, especially with the recent interest in hip preservation.[3,7] The other is that certain hospitals are more of a referral centre for such hip preservation procedures skewing their data. Most likely it is a combination of both.

The final question is the increasing number of complications seen over time. Does it reflect the increasing number of more complex procedures, such as open reduction internal fixation via a modified Dunn osteotomy,[14-17] and will it decrease after a learning curve with only select surgeons performing the procedure?[14,16] The hip preservation aspect of such surgeries will not be known until there is long-term follow-up, at least 20 to 30 years after the index procedure.[18] All of these questions need to be revisited ten to 20 years from now to understand the outcomes and changes in SCFE treatment presented here.

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COMPLIANCE WITH ETHICAL STANDARDS

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ETHICAL STATEMENT

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